SEISMIC HAZARD ZONE REPORT 100

SEISMIC HAZARD ZONE REPORT FOR THE ACTON 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

STATE OF CALIFORNIA
GRAY DAVIS
GOVERNOR

THE RESOURCES AGENCY
MARY D. NICHOLS
SECRETARY FOR RESOURCES

DEPARTMENT OF CONSERVATION
DARRYL YOUNG
DIRECTOR

CALIFORNIA GEOLOGICAL SURVEY
MICHAEL S. REICHLE, *ACTING STATE GEOLOGIST*

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ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Acton 7.5-Minute Quadrangle, Los Angeles County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area, mostly the northern half, of approximately 37 square miles at a scale of 1 inch = 2,000 feet.

The quadrangle lies in central Los Angeles County about 20 miles east of the Santa Clarita Civic Center and 27 miles north of the Los Angeles Civic Center. All land is unincorporated Los Angeles County land, including the rural community of Acton, and the southern half lies within the Angeles National Forest. The Santa Clara River flows across the quadrangle southwestward to the village of Acton where it turns south for two miles then turns westward, enters steep-walled Soledad Canyon and exits at the center of the western boundary. Along the southern boundary the San Gabriel Mountains reach 6,502 feet on Mount Gleason. The lowest elevation is about 2,320 feet on the Santa Clara River at the western boundary. North and east of Acton are broad aprons of older alluvium. Aliso Canyon and its tributary, Gleason Canyon, drain the eastern part of the area. Several large canyons dissect the mountainous terrain south of the Santa Clara River. Access to the region is via the Antelope Valley Freeway (State Highway14), Soledad Canyon Road, Escondido Canyon Road, Aliso Canyon Road and Forest Service roads. Development currently is limited to rural homes, small ranches, and recreational facilities, especially along Soledad Canyon.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

In the Acton Quadrangle the liquefaction zone is restricted to the bottoms of Soledad Canyon and its major tributary canyons. Most bedrock in the quadrangle consists of plutonic and metamorphic rocks with some Tertiary sedimentary and volcanic rocks. Although these rocks are typically not weak, steep slopes are widespread where rock falls and slides could be generated by earthquakes. These conditions contribute to an earthquake-induced landslide zone that covers about 18 percent of the evaluated portion of the quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
945 Bryant Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997b). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

The Act directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. The Act also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Acton 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Acton 7.5-Minute Quadrangle, Los Angeles County, California

By
Elise Mattison and Janis L. Hernandez

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997b). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

Following the release of DMG Special Publication 117 (DOC, 1997b), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC).

The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Acton 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking) complete the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, including areas in the Acton Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Ground-water maps constructed to show the historically highest known ground-water levels

- Geotechnical data analyzed to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on CGS probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Acton Quadrangle consist mainly of alluviated valleys and canyons. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Acton Quadrangle covers about 62 square miles in central Los Angeles County. The center of the area is 20 miles east of the Santa Clarita Civic Center and 27 miles north of the Los Angeles Civic Center. The entire quadrangle consists of unincorporated Los Angeles County land, including the rural community of Acton. The southern half of the quadrangle lies within the Angeles National Forest. About 37 square miles of the quadrangle were evaluated for zoning.

The Santa Clara River flows across the quadrangle southwestward to the village of Acton where it turns south for two miles then turns west, enters steep-walled Soledad Canyon and exits at the center of the western boundary. South of the canyon the steep north-facing slope of the San Gabriel Mountains contain deep canyons in crystalline basement rocks. The crest of the mountains along the southern boundary reaches 6,502 feet on Mount Gleason. The lowest elevation in the quadrangle is about 2,320 feet on the Santa Clara River at the western boundary. North and east of Acton the physiography contrasts with that elsewhere in the quadrangle because it includes broad aprons of older alluvium. Several large canyons drain large areas within the Acton Quadrangle. Aliso Canyon and its tributary, Gleason Canyon, drain the eastern part of the area. Several large canyons dissect the mountainous terrain south of the Santa Clara River. The creeks in them originate just below the crest of the ridge along the southern boundary.

Access to the region is via the Antelope Valley Freeway (State Highway 14), which crosses the northern edge of the area. Soledad Canyon, Escondido Canyon, and Aliso Canyon roads and Forest Service roads in the national forest provide additional access. At present, development is limited to rural homes, small ranches, and recreational facilities, especially along Soledad Canyon.

GEOLOGY

Bedrock and Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. For this evaluation, CGS staff digitized the Dibblee Geological Foundation's geologic map (Dibblee, 1996) and modified it by removing landslide deposits and revising contacts between bedrock and surficial units to better conform to the topographic contours of the U.S. Geological Survey 7.5-minute quadrangle. CGS staff further refined the contacts by reviewing air-photos and digital orthophoto quarter quadrangles, and with field reconnaissance. The distribution of Quaternary deposits on this map was used in combination with other data, discussed below, to evaluate liquefaction susceptibility and develop the Seismic Hazard Zone Map (Plate 1.1).

Dibblee (1996) mapped late Pleistocene dissected valley and terrace deposits of sand and gravel (Qoa) derived primarily from crystalline rock sources on the slopes adjacent to most of the canyons in the Acton Quadrangle (Table 1.1). The valleys and canyon flood plains contain Holocene alluvial gravel, sand, and silt (Qa) and the major active stream channels (Soledad, Aliso, Kentucky Springs, and Arrastre canyons) contain gravel and sand mapped as Qg. Three small residential developments in the central part of the quadrangle sit on artificial fill (af).

Map Unit	Description	Age
af	artificial fill	Holocene
Qg	gravel and sand of major stream channels	Holocene
Qa	alluvial gravel, sand and clay of valley areas	Holocene
Qoa	alluvial sand and gravel of mostly plutonic rock detritus	Pleistocene

Table 1.1. Quaternary Map Units Used in the Acton Quadrangle as Shown on Plate1.1 (after Dibblee, 1996).

Pleistocene surficial sediments rest unconformably on Tertiary sedimentary and volcanic rocks, which unconformably overlie Mesozoic to Precambrian crystalline rocks. Precambrian rocks include gneissic rocks and an anorthosite-gabbro complex. Triassic rocks consist of hornblende diorite-gabbro, exposed mostly in the central to northeastern part of the Acton Quadrangle, and Lowe Granodiorite, mapped in the southeastern corner; on Parker Mountain, north of Soledad Canyon; and in the central to east-central part of the quadrangle, on both sides of the middle reaches of Aliso Canyon. Late Mesozoic granitic rocks crop out between Aliso and Arrastre canyons.

Tertiary andesitic rocks intrude the granitic unit and are exposed just north of the center of the Acton Quadrangle. Sedimentary and volcanic rocks of the lower part of the Tertiary Vasquez Formation crop out mostly north of Soledad Canyon. See the earthquake-induced landslide portion (Section 2) of this report for further details.

Structural Geology

The dominant structural element within the Acton Quadrangle is the San Gabriel Mountains basement complex, which covers most of the quadrangle and is locally incised by Aliso, Soledad and Moody canyons, including smaller canyons roughly oriented northwest. The northern portion of the map area is characterized by the eastern portion of the Soledad Basin, which is a southwest-plunging syncline that includes strata of the Vasquez Formation (Muehlberger, 1958). Numerous northeast-striking faults cut across the sedimentary rocks of the Soledad Basin and the basement rocks in the San Gabriel Mountains. These include the Lone Tree, Soledad and several unnamed faults. None of these faults has recognized Holocene fault movement and, therefore, no fault rupture hazard zones have been delineated within the mapped area (DOC, 1997a). However, the San Andreas Fault Zone is 3.5 miles north of the Acton Quadrangle and could contribute strong ground shaking to the study area (see Section 3 of this report).

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of Quaternary deposits was obtained from borehole and trench logs collected from reports on geotechnical projects. For this investigation, logs were collected from the files of Earth

Systems Consultants and the Los Angeles County Department of Public Works. Data from 20 logs were entered into a CGS geotechnical GIS database.

Standard Penetration Tests (SPTs) provide a standardized measure of the penetration resistance of geologic deposits and are commonly used as an index of soil density. This in-field test consists of counting the number of blows required to drive a split-spoon sampler (1.375-inch inside diameter) one foot into the soil at the bottom of a borehole at chosen intervals while drilling. The driving force is provided by dropping a 140-pound hammer weight 30 inches. The SPT method is formally defined and specified by the American Society for Testing and Materials in test method D1586 (ASTM, 1999). Recorded blow counts for non-SPT geotechnical sampling where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), are converted to SPT-equivalent blow counts. The actual and converted SPT blow counts are normalized to a common-reference, effective-overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

Geotechnical and environmental borehole and trench logs provided information on lithologic and engineering characteristics of Quaternary deposits within the study area. Geotechnical characteristics of the Quaternary map units are generalized in Table 1.2.

Geologic Map Unit	Description	Material Type	Consistency	Age	Susceptible to Liquefacton?*
af	artificial fill	man-made deposits of earth materials derived from local sources	loose to dense	latest Holocene	yes
Qg	major stream channel sediment	gravel and sand	loose	late Holocene	yes
Qa	valley alluvium	gravel, sand and clay	loose	Holocene	yes
Qoa	dissected valley and terrace sediments	alluvial sand and gravel of mostly plutonic rock detritus	dense	Pleistocene	no

* when saturated

Table 1.2. Quaternary Map Units Used in the Acton 7.5-Minute Quadrangle and Their Geotechnical Characteristics and Liquefaction Susceptibility

GROUND WATER

Saturation reduces the effective normal stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973), which typically occurs where ground water is shallower than about 50 feet (SCEC, 1999). Item 4a of the SMGB criteria for delineating seismic hazard zones in California (DOC, 2000; Criteria for Zoning section of this report) excludes saturated deposits deeper than 40 feet below the surface. CGS liquefaction evaluations, therefore, concentrate on areas where investigations indicate that young Quaternary sediment might be saturated within 40 feet of the ground surface.

Natural processes and human activities can cause ground-water fluctuations, making it impossible to anticipate future water levels. In its analysis of geologic data, CGS uses the shallowest ground-water levels known, to accommodate the possibility of deep ground water returning to historically shallow levels. This has occurred in basins where water-importing urbanized areas have replaced vast farm and orchard lands that were characterized by substantial ground-water withdrawal (for example, Simi Valley, Ventura County) as well as in basins where large-scale ground-water recharge programs are employed.

Plate 1.2 depicts historically shallowest ground water in alluviated areas of the Acton Quadrangle. Water was measured at 10 feet below the surface in Soledad Canyon and is assumed to have reached similarly shallow levels, historically, in other active washes and restricted canyons.

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. CGS's qualitative relations between susceptibility and geologic map unit are summarized in Table 1.2.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Acton Quadrangle, PGAs of 0.53 to 6.0 g, resulting from an earthquake of magnitude 7.8 were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Cramer and Petersen, 1996; Petersen and others, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983;

National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were collected. Typically, multiple samples are collected for each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated by the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 20 geotechnical borehole and trench logs reviewed in this study (Plate 1.2), 14 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Acton Quadrangle is summarized below.

Areas of Past Liquefaction

Documentation of historical liquefaction or paleoseismic liquefaction in the Acton Quadrangle was not found during this study.

Artificial Fills

In the Acton Quadrangle, artificial fill areas large enough to show at the scale of mapping are limited to housing developments along Country Way and Calmgarden Road (southeast of the intersection of Crown Valley Road and Soledad Canyon Road), along Shadow Canyon Road, Camino Canyon Road and El Dorado Drive, off Aliso Canyon Road. Because these fills are not considered saturated by ground water, they are not included in the zone of required investigation for liquefaction.

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions are scarce for saturated young Quaternary deposits. Therefore, staff depended significantly on SMGB Criteria Item 4 (see above) for zoning for liquefaction in the Acton Quadrangle.

Areas with Insufficient Existing Geotechnical Data

Staff depended significantly on SMGB Criteria Item 4 (see above) for zoning for liquefaction in the Acton Quadrangle because available geotechnical data were marginally adequate for evaluating liquefaction potential. Borehole and trench logs indicate loose, sandy material that could liquefy where saturated under historically shallowest ground-water conditions presented on Plate 1.2.

ACKNOWLEDGMENTS

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Acton 7.5-Minute Quadrangle, Los Angeles County, California

By
Rick I. Wilson and Janis L. Hernandez

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Acton 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking), complete the report, which is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Acton Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area.

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared.

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area.

- Seismological data in the form of CGS probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area.

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a CGS pilot study (McCrink and Real, 1996; McCrink, 2001) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Acton Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Acton Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Acton Quadrangle covers about 62 square miles in central Los Angeles County. The center of the area is 20 miles east of the Santa Clarita Civic Center and 27 miles north of the Los Angeles Civic Center. The entire quadrangle consists of unincorporated Los Angeles County land, including the rural community of Acton. The southern half of the quadrangle lies within the Angeles National Forest. About 37 square miles of the quadrangle, comprising mostly the northern half, were evaluated for zoning.

The Santa Clara River flows across the quadrangle southwestward to the village of Acton where it turns south for two miles then turns westward, enters steep-walled Soledad Canyon and exits at the center of the western boundary. South of the canyon the steep north-facing slope of the San Gabriel Mountains contain deep canyons in crystalline basement rocks. The crest of the mountains along the southern boundary reaches 6,502 feet on Mount Gleason. The lowest elevation in the quadrangle is about 2,320 feet on the Santa Clara River at the western boundary. North and east of Acton the physiography contrasts with that elsewhere in the quadrangle because it includes broad aprons of older alluvium. Several large canyons drain large areas within the Acton Quadrangle. Aliso Canyon and its tributary, Gleason Canyon, drain the eastern part of the area. Several large canyons dissect the mountainous terrain south of the Santa Clara River. The creeks in them originate just below the crest of the ridge along the southern boundary.

Access to the region is via the Antelope Valley Freeway (State Highway14), which crosses the northern edge of the area. Soledad Canyon Road, Escondido Canyon Road, Aliso Canyon Road and Forest Service roads in the national forest provide additional access. At present, development is limited to rural homes, small ranches, and recreational facilities, especially along Soledad Canyon.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Acton Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1957 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

Areas that have undergone large-scale grading since 1957 in the hilly portions of the quadrangle were updated to reflect the new topography. A DEM reflecting this recent grading, specifically along State Highway 14, was obtained from an airborne interferometric radar sensor flown in 2001, with an estimated vertical accuracy of approximately 1.5 meters (Intermap Corporation, 2002). An interferometric radar DEM is prone to creating false topography where tall buildings, metal structures, or trees are present. The DEM used for the graded areas within the Acton Quadrangle underwent additional processing to remove these types of artifacts (Wang and others, 2001). Due to the low-lying chaparral vegetation and relatively small-structure/residential construction types present, this type of DEM is appropriate for use in the Acton Quadrangle. Nevertheless, the final hazard zone map was checked for potential errors of this sort and corrected. Graded areas, where the radar DEM was applied, are shown on Plate 2.1.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The bedrock geologic map used in this slope stability evaluation was obtained from the Dibblee Geological Foundation (Dibblee, 1996) and digitized by CGS staff for this study. Bedrock units are described in detail in this section. Quaternary surficial geologic units are briefly described here and are discussed in more detail in Section 1, Liquefaction Evaluation Report.

CGS geologists modified the digital geologic map in the following ways. Landslide deposits were deleted from the map so that the distribution of bedrock formations and the newly created landslide inventory would exist on separate layers for the hazard analysis. Contacts between bedrock and surficial units were revised to better conform to the topographic contours of the U.S. Geological Survey 7.5-minute quadrangle. Air-photo interpretation, digital orthophoto quarter quadrangle photo review, and field reconnaissance was performed to assist in adjusting contacts between bedrock and surficial geologic units, and to review geologic unit lithology and geologic structure. Additionally, the digital geologic map was modified to include interpretations of observations made during the aerial photograph review for the landslide inventory and field reconnaissance. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to the development and abundance of landslides was noted.

The bedrock geology for the Acton Quadrangle consists of Precambrian to Mesozoic crystalline rocks and Tertiary sedimentary units. A complex pre-Cenozoic history of intrusion and metamorphism has resulted in a variety of basement rock types in the Acton Quadrangle. The oldest rocks in the quadrangle are Precambrian gneissic rocks. Small bodies of these rocks include a dark gray dioritic gneiss (map symbol dgn), a gray granodiorite gneiss (ggn) and a dark gray, foliated schistose gneiss (msg). The gneissic rocks occur as inclusions in the crystalline bedrock belonging to the regionally extensive San Gabriel anorthosite-gabbro complex.

The San Gabriel anorthosite-gabbro complex, also of Precambrian age (Oakshott, 1958; Ehlig, 1975; Carter, 1980, 1982) covers a large portion of the map area. As depicted on Dibblee's (1996) map, this zoned crystalline bedrock contains light gray to bright white anorthosite (an). It hosts scattered thin mafic and aplite dikes. Additionally, this group of zoned crystalline rocks includes a light gray leucogabbro (lgb), a tan to light rusty brown syenite (sy), and a dark gray gneissic hornblende gabbro (hgb). Generally, where relatively fresh these crystalline rocks are hard and moderately fractured. They typically weather to a fine grus.

Triassic hornblende diorite-gabbro plutonic rocks (hdg) intrude the anorthosite-gabbro crystalline basement rocks (Dibblee, 1996). This crystalline rock is dark gray, medium to coarse grained, and consists mostly of hornblende and plagioclase feldspar. The Lowe Granodiorite intrusive rocks were emplaced during early Triassic time. Lowe Granodiorite is exposed in the Acton Quadrangle as four distinct facies (Dibblee, 1996). These facies are: 1) a biotite facies (lgdb), which is biotite and hornblende rich, with minor quartz; 2) a medium gray porphyritic facies (lgdp), which has characteristic large potassium feldspar phenocrysts or porphyroblasts and scattered euhedral garnets; 3) a light tan to white facies (lgdh) containing small clustered hornblende crystals, and slightly gneissic texture; and 4) a darker facies with abundant hornblende and/or biotite (lgdd) which is associated with inclusions of the Precambrian diorite gneiss (dgn, as described above).

Late Cretaceous granitic rocks, which range from granite to quartz diorite, intrude the Lowe Granodiorite. The granite is white to tan and is medium to fine grained (map symbol gr), and the quartz diorite (map symbol qd) is light to medium gray with predominantly plagioclase feldspar (Dibblee, 1996). Scattered outcrops of dark gray, fine-grained mafic dikes intrude the granitic rocks, most are massive and highly altered. Few areas exposed are of mappable size, and these dikes cut all crystalline rocks. Generally, these crystalline bedrock materials weather into smaller rock fragments and abundant grus.

Oligocene andesitic intrusive rocks (Tai) intrude the Cretaceous granitic rocks. The Oligocene intrusives are grayish brown, aphanitic to fine-grained andesite with partial breccia texture and elongate pod shape intrusives, exclusively mapped within the granitic rocks. The andesite is resistant, but highly fractured, with nearly vertical margins (Dibblee, 1996).

Oligocene sedimentary and volcanic rocks of the Vasquez Formation overlie the older intrusive rocks. The Vasquez Formation consists of non-marine alluvial flood plain and stream sediments, and fanglomerate deposits of mostly reddish brown to maroon arkosic sandstone, sedimentary breccia, conglomerate, and interbedded subaerial andesitic volcanic rocks. Dibblee (1996) mapped many subunits in the Vasquez Formation. The subunits include dark gray to dark brown andesitic flow and flow-breccia deposits (Tva, Tvb, and Tvbb) that are locally amigdaloidal, hard, and generally weather into blocks with little soil development. Other Vasquez units include a variety of light brown to maroon with gray conglomerate/sedimentary breccia units (Tvcal, Tvcgl, Tvcd, Tvcs, Tvcg).

Quaternary surficial sediments unconformably overlie the deformed Tertiary strata and older crystalline rocks. Pleistocene unconsolidated older alluvial deposits (Qoa) are located in Aliso, Soledad, Moody and Gleason canyons in the central portion of the study area. These deposits are slightly elevated areas of dissected coarse alluvial sand, gravel and some boulders, composed of mostly crystalline bedrock fragments. Younger surficial sediments (Qa) of Holocene age contain gravel with minor sand and silt within the valleys and canyon floodplains. Active channel deposits containing boulders, gravel and sand (Qg) are located within the drainage channels of the active creek areas and smaller tributaries. Landslide deposits (Qls) are discussed later in this report. Modern fill (af), mostly related to road construction, occurs in scattered places across the map. A more detailed discussion of the Quaternary deposits in the Agua Dulce Quadrangle can be found in Section 1.

Structural Geology

The dominant structural element within the Acton Quadrangle is the San Gabriel Mountains basement complex, which covers most of the quadrangle and is locally incised by Aliso, Soledad and Moody canyons. The Soledad Basin, which is a southwest-plunging syncline that includes strata of the Vasquez Formation (Jahns and Muehlberger, 1958; Muehlberger, 1958), underlies the northern portion of the quadrangle. Numerous northeast-striking faults cut across the sedimentary rocks of the Soledad Basin and the basement rocks in the San Gabriel Mountains. These include the Lone Tree, Soledad and several unnamed faults. None of these faults have recognized Holocene fault movement.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Acton Quadrangle was prepared by field reconnaissance and analysis of stereo-paired aerial photographs. Also carried out was a review of digital orthophoto quarter-quadrangle files, and both previously published (Morton and Streitz, 1969; Dibblee, 1996) and unpublished (Hart, 2001) landslide maps.

Landslides were mapped at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the landslide zoning as described later in this report. Landslides rated as questionable were not carried into the slope stability analysis due to the uncertainty of their existence. The completed landslide map was digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

Landslides are not common within the Acton Quadrangle, however a few large older rockslides were observed within the crystalline granodiorite bedrock materials, and several small to moderate-size debris slides, rockslides and debris flows were mapped within the Tertiary units. Because it is not within the scope of the Act to review and monitor grading practices to ensure past slope failures have been properly mitigated, all documented slope failures, whether or not surface expression currently exists, are included in the landslide inventory.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the units identified on the Acton Quadrangle geologic map were obtained from the Los Angeles County Public Works Department (see Appendix A). The locations of rock and soil samples taken for shear testing within the Acton Quadrangle are shown on Plate 2.1. Material strength information from the nearby Agua Dulce, Pacifico Mountain, Mint Canyon, and Ritter Ridge quadrangles were used for several geologic formations for which no or little shear test information was available within the Acton Quadrangle.

Shear strength data gathered from the above source was compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean or median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups (Table 2.2) in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

Members of the Vasquez Formation (Tvcgl, Tvcal, Tvb, Tvbb, Tva, Tvcs, Tvcg, and Tvcd) were subdivided further, as described below.

Adverse Bedding Conditions

Adverse bedding conditions are an important consideration in slope stability analyses. Adverse bedding conditions occur where the dip direction of bedded sedimentary rocks is roughly the same as the slope aspect, and where the dip magnitude is less than the slope gradient. Under these conditions, landslides can slip along bedding surfaces due to a lack of lateral support.

To account for adverse bedding in our slope stability evaluation, we used geologic structural data in combination with digital terrain data to identify areas with potentially adverse bedding, using methods similar to those of Brabb (1983). The structural data, derived from the geologic map database, were used to categorize areas of common bedding dip direction and magnitude. The dip direction was then compared to the slope aspect and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, but greater than 25 percent (4:1 slope), the area was marked as a potential adverse bedding area.

The Vasquez Formation, which contains varying amounts of interbedded sandstone, shale, and volcanic rock, was subdivided based on shear strength differences between hard volcanic and/or coarse-grained layers (higher strength), and highly weathered and/or fine-grained (lower strength) layers. Shear strength values for the equivalent higher and lower strength lithologic types were then applied to areas of favorable and adverse bedding orientation, which were determined from structural and terrain data as discussed above. It was assumed that higher material strength dominates where bedding dips into a slope (favorable bedding) while lower material strength dominates where bedding dips out of a slope (adverse bedding). The geologic material strength map was modified by assigning the lower, fine-grained shear strength values to areas where potential adverse bedding conditions were identified. The favorable and adverse bedding shear strength parameters for the Vasquez Formation are included in Table 2.1.

Existing Landslides

As discussed later in this report, the criteria for landslide zone mapping state that all existing landslides that are mapped as definite or probable are automatically included in the landslide zone of required investigation. Therefore, an evaluation of shear strength parameters for existing landslides is not necessary for the preparation of the zone map. However, in the interest of completeness for the material strength map, to provide relevant material strength information to project plan reviewers, and to allow for future revisions of our zone mapping procedures, we have collected and compiled shear strength data considered representative of existing landslides within the quadrangle.

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily "residual" strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used.

Within the Acton Quadrangle, no shear tests of landslide slip surface materials were available for this study. The phi value presented in Table 2.1 reflects the values found in nearby and adjacent quadrangles for similar materials.

ACTON QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	sy	5	38/39	38/38	259/200	msg ggn dgn lgb hgb lgdd Tvcg(fbc) Tvcd(fbc)	38
	hgd	10	38/35				
	lgdb	11	38/37				
	lgdp	6	39/39				
	lgdh	9	38/37				
	Tvcgl(fbc)	4	40/39				
GROUP 2	gr	11	35/34	34/35	248/200	an Tai Tvcal(fbc) Tva(fbc) Tvbb(fbc) Tvcs(fbc) Tvcg(abc) Tvcd(abc) Qg	34
	Tvb(fbc)	19	35/35				
	Qoa	114	35/35				
	Qa	17	33/33				
GROUP 3	af	9	29/30	29/30	280/225	Tvcgl(abc) Tpcal(abc) Tvcs(abc) rc	30*
GROUP 4	Tvb(abc)	3	28/26	28/26	475/200	Tva(abc) Tvbb(abc)	26*
GROUP 5						Qls	16

* Median shear strength value was used in the stability analysis due to so few numbers in the sample set.
abc = adverse bedding condition, fine-grained material strength
fbc = favorable bedding condition, coarse-grained material strength
Formation abbreviations from Dibblee (1996)

Table 2.1. Summary of the Shear Strength Statistics for the Acton Quadrangle.

SHEAR STRENGTH GROUPS FOR THE ACTON QUADRANGLE				
GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
msg, ggn	an, gr, Tai	Tvcgl(abc)	Tvb(abc)	Qls
dgn, sy, lgb	Tvcal(fbc)	Tvcal(abc)	Tvbb(abc)	
hgb, hgd	Tvb(fbc)	Tvcs(abc)	Tva(abc)	
lgdb, lgdp	Tvbb(fbc)	rc, af		
lgdh, lgdd	Tba(fbc)			
Tvcgl(fbc)	Tvcs(fbc)			
Tvcg(fbc)	Tvcg(abc)			
Tvcd(fbc)	Tvcd(abc)			
	Qoa, Qa, Qg			

Table 2.2. Summary of Shear Strength Groups for the Acton Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Acton Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by CGS for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.6 to 7.8
Modal Distance:	7.8 to 19.6 km
PGA:	0.49 to 0.66 g

The strong-motion record selected for the slope stability analysis in the Acton Quadrangle was the Southern California Edison Lucerne record from the 1992 magnitude

7.3 Landers, California, earthquake. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the values from the Lucerne record do not fall within the range of the probabilistic parameters, this record was considered to be sufficiently conservative to be used in the stability analyses. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.14, 0.18 and 0.24g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Acton Quadrangle.

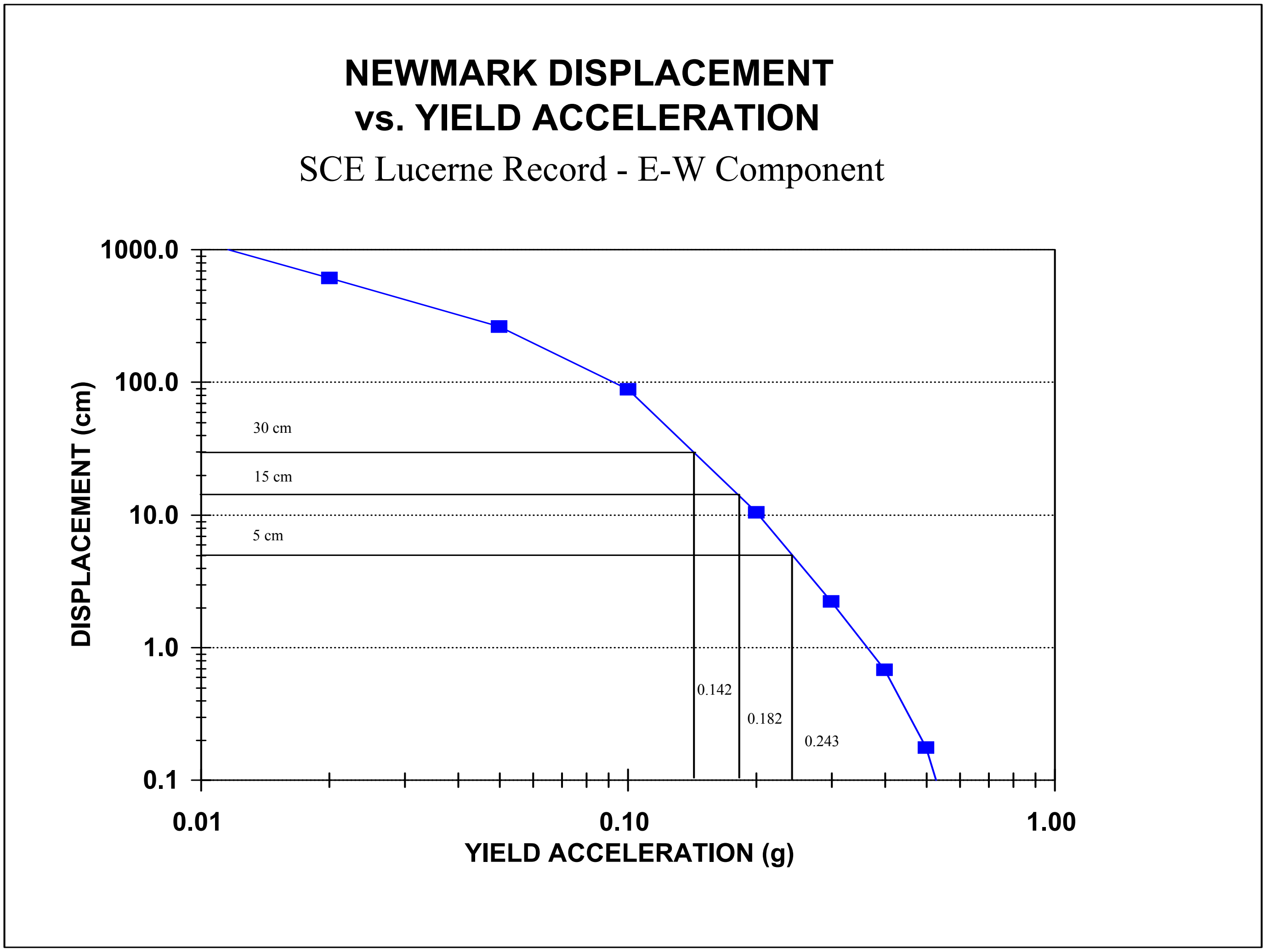

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the 1992 Landers Earthquake - Lucerne Record.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where **FS** is the Factor of Safety, **g** is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.14g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned.

2. If the calculated yield acceleration fell between 0.14g and 0.18g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned.

3. If the calculated yield acceleration fell between 0.18g and 0.24g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned.

4. If the calculated yield acceleration was greater than 0.24g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

ACTON QUADRANGLE HAZARD POTENTIAL MATRIX

Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	**Low**	**Moderate**	**High**
1 (38)	0 to 49%	49 to 57%	57 to 62%	> 62%
2 (34)	0 to 41%	41 to 48%	48 to 52%	> 52%
3 (30)	0 to 31%	31 to 37%	37 to 41%	> 41%
4 (26)	0 to 24%	24 to 30%	30 to 33%	> 33%
5 (16)	0 to 5%	5 to 10%	10 to 14%	> 14%

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Acton 7.5-Minute Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 cm or greater. Areas with a Very Low hazard potential, indicating less than 5 cm displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slope gradients.

2. Geologic Strength Group 4 is included for all slopes steeper than 24 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 31 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 41 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 49 percent.

This results in 18 percent of the mapped area of the quadrangle lying within the earthquake-induced landslide hazard zone for the Acton Quadrangle.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Charles Nestle, Greg Johnson and Robert Larson from Los Angeles County Public Works provided assistance with data collection for Los Angeles County. Earl Hart made a preliminary landslide map of the quadrangle. Terilee McGuire, Barbara Wanish, Lee Wallinder and Bob Moscovitz provided GIS support at CGS. Barbara Wanish and Diane Vaughn prepared the final landslide hazard zone maps and the graphic displays for this report.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Public Works Department	**128**
Total Number of Shear Tests	**128**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Acton 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen*, Chris H. Cramer*, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation
California Geological Survey
***Formerly with CGS, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight

ACTON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS

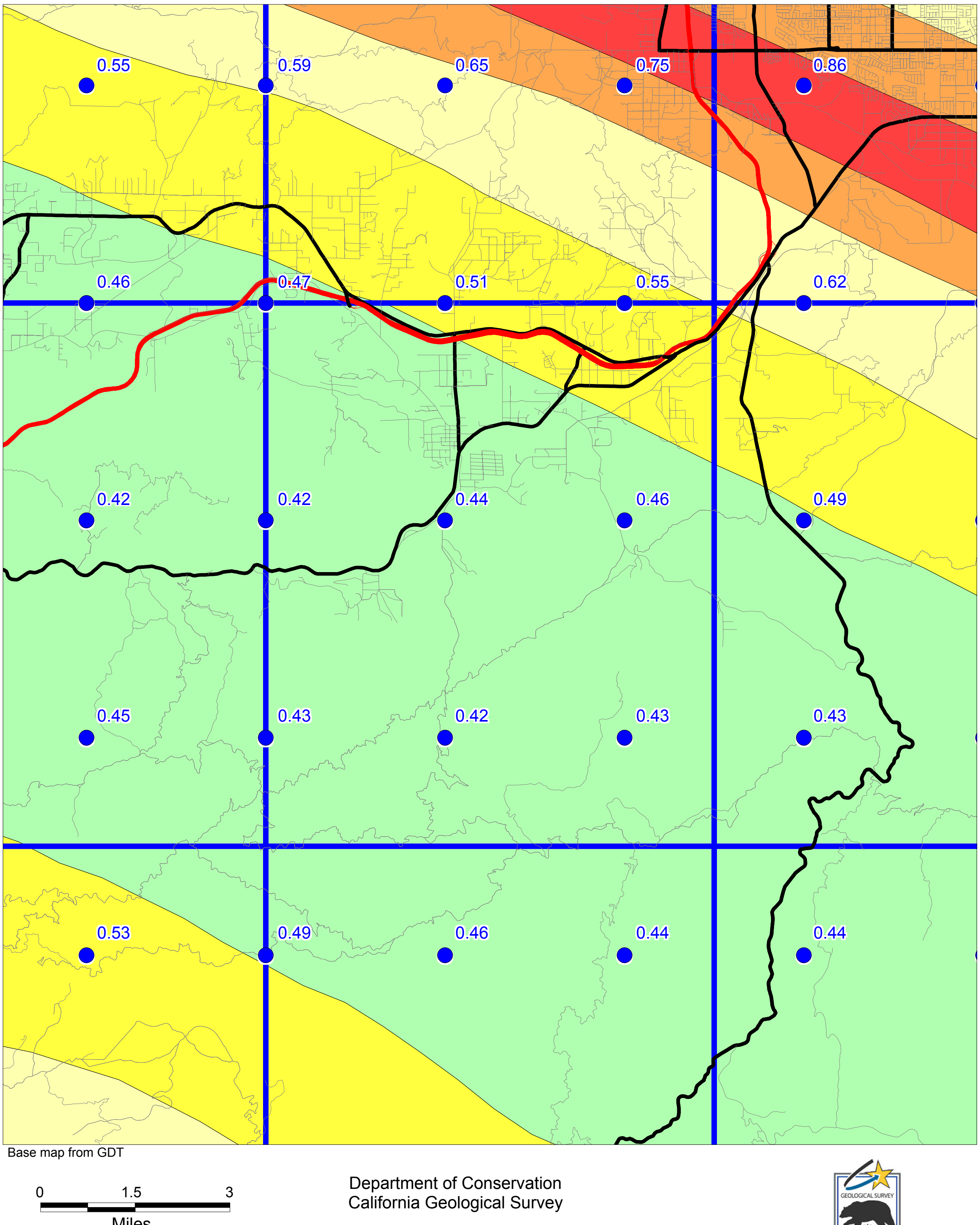

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Figure 3.1

ACTON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS

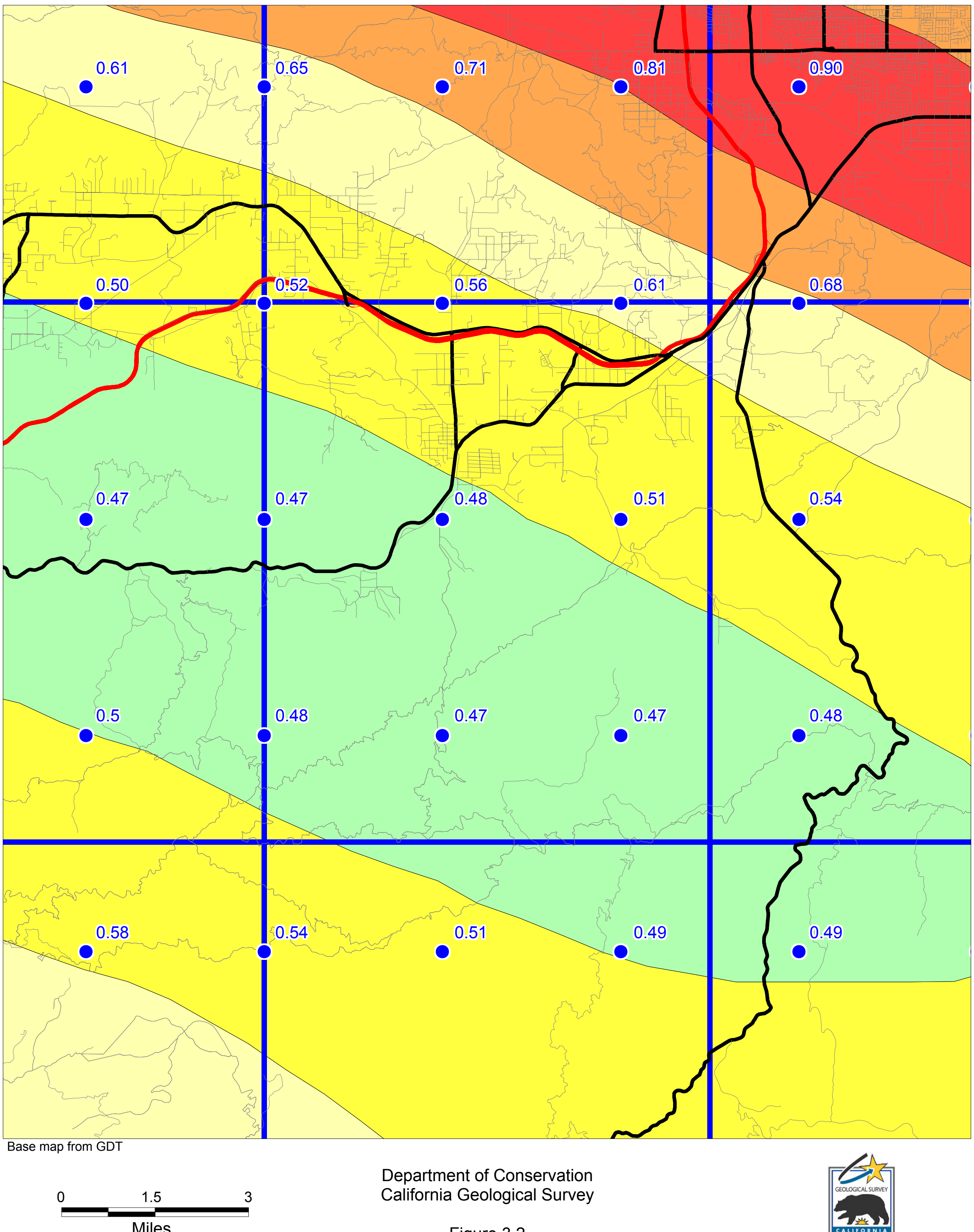

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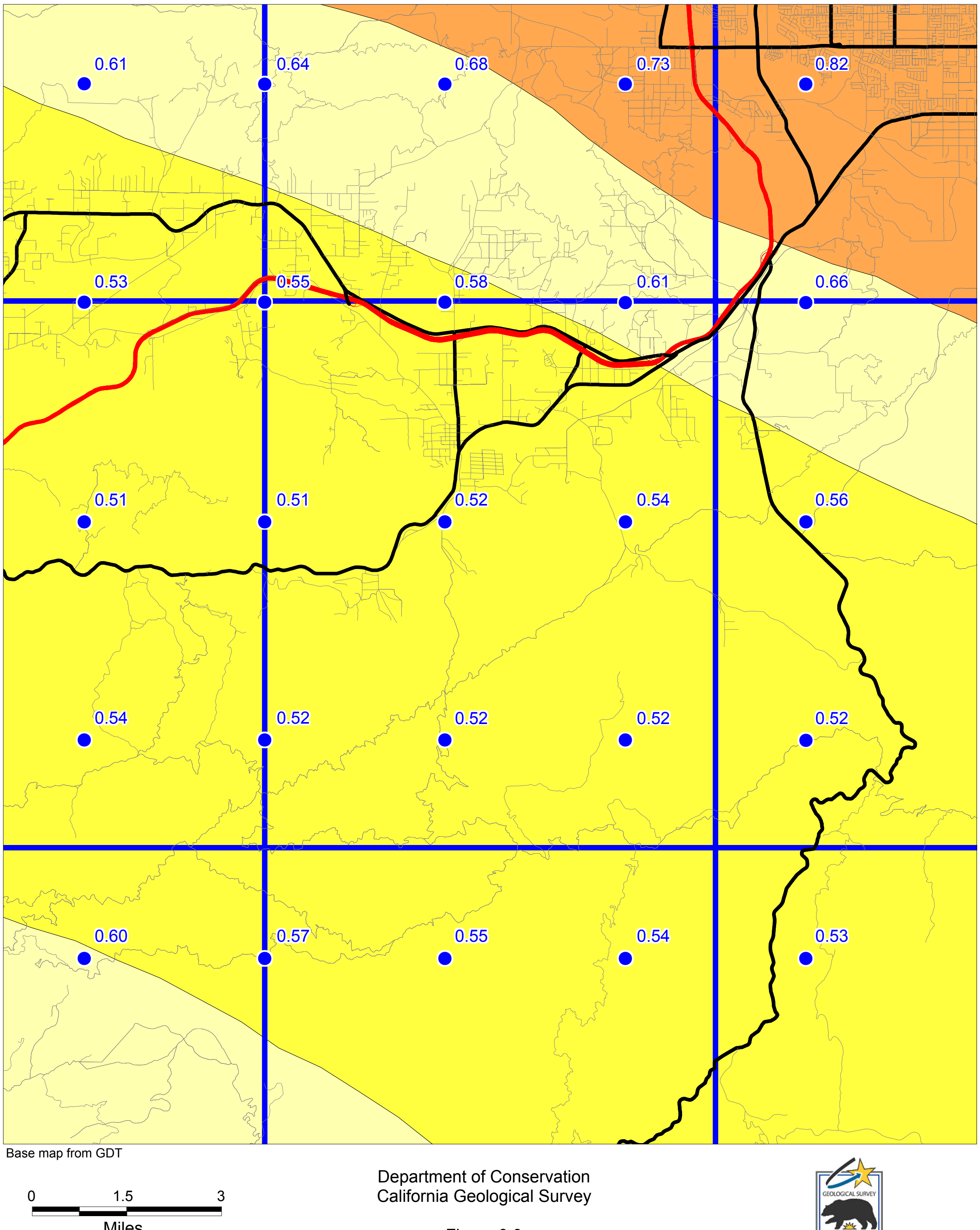
Figure 3.2

ACTON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Department of Conservation
California Geological Survey

Figure 3.3

adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

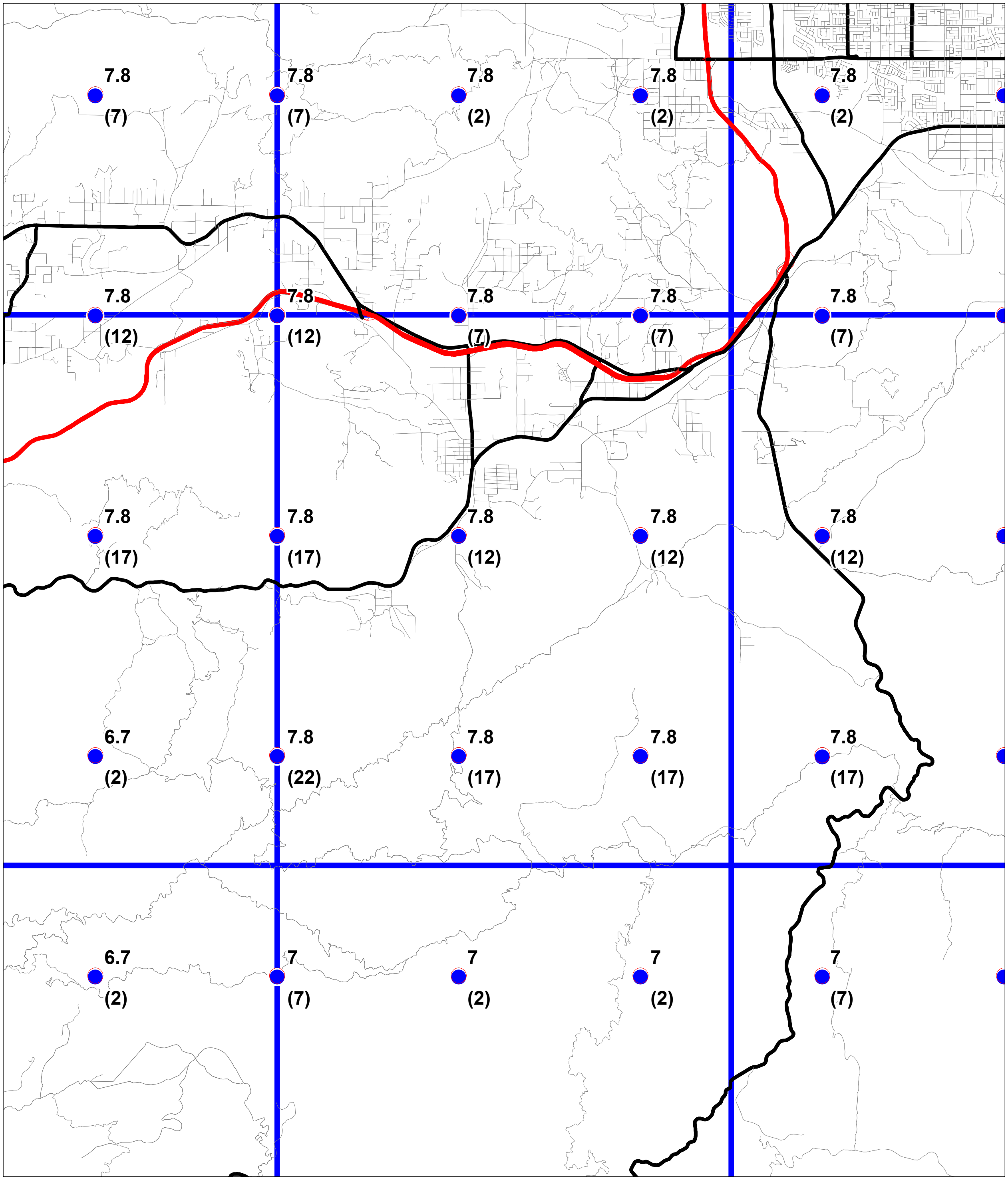
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

ACTON 7.5 MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey
Figure 3.4

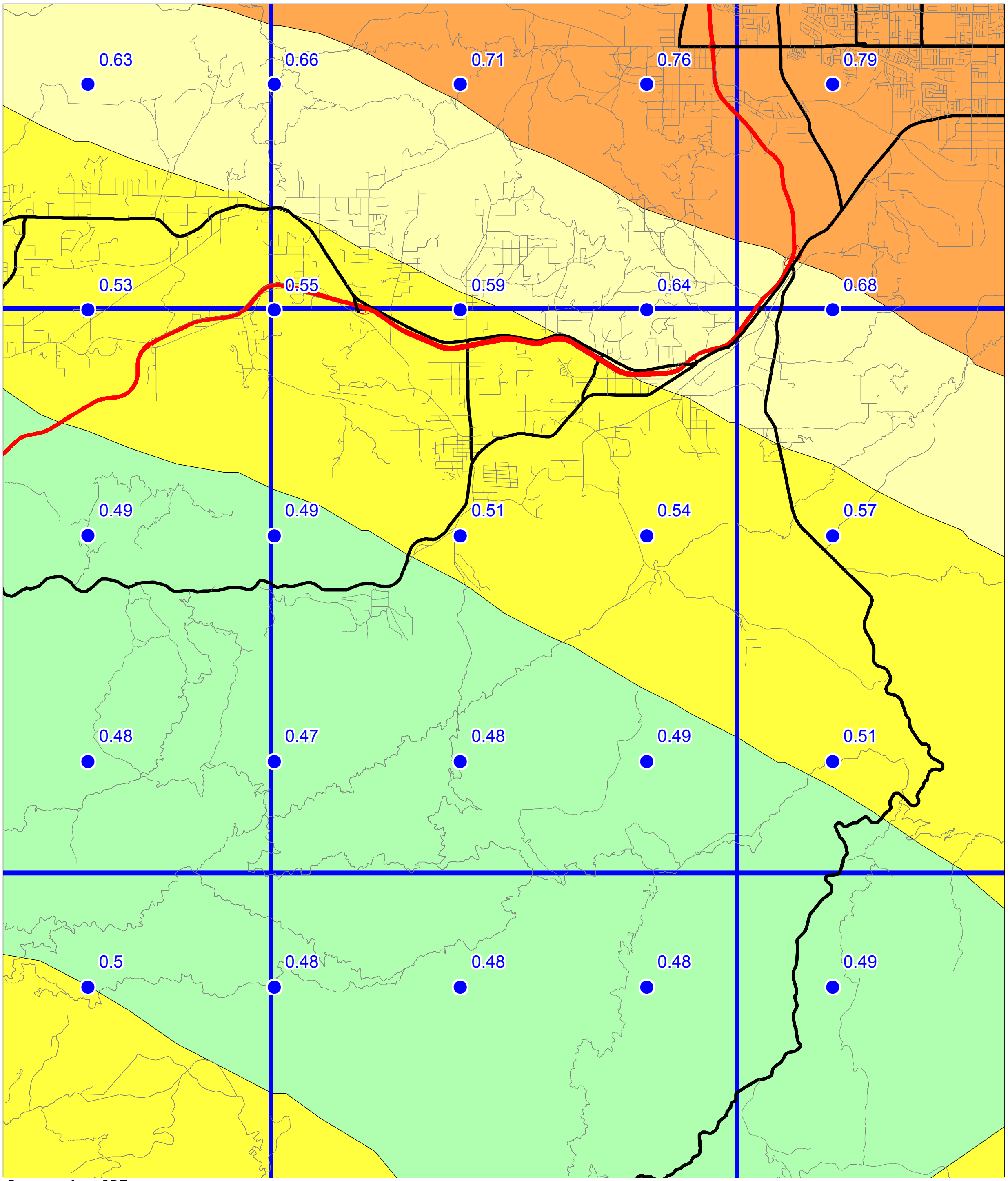
2003 **SEISMIC HAZARD EVALUATION OF THE ACTON QUADRANGLE**

ACTON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3

Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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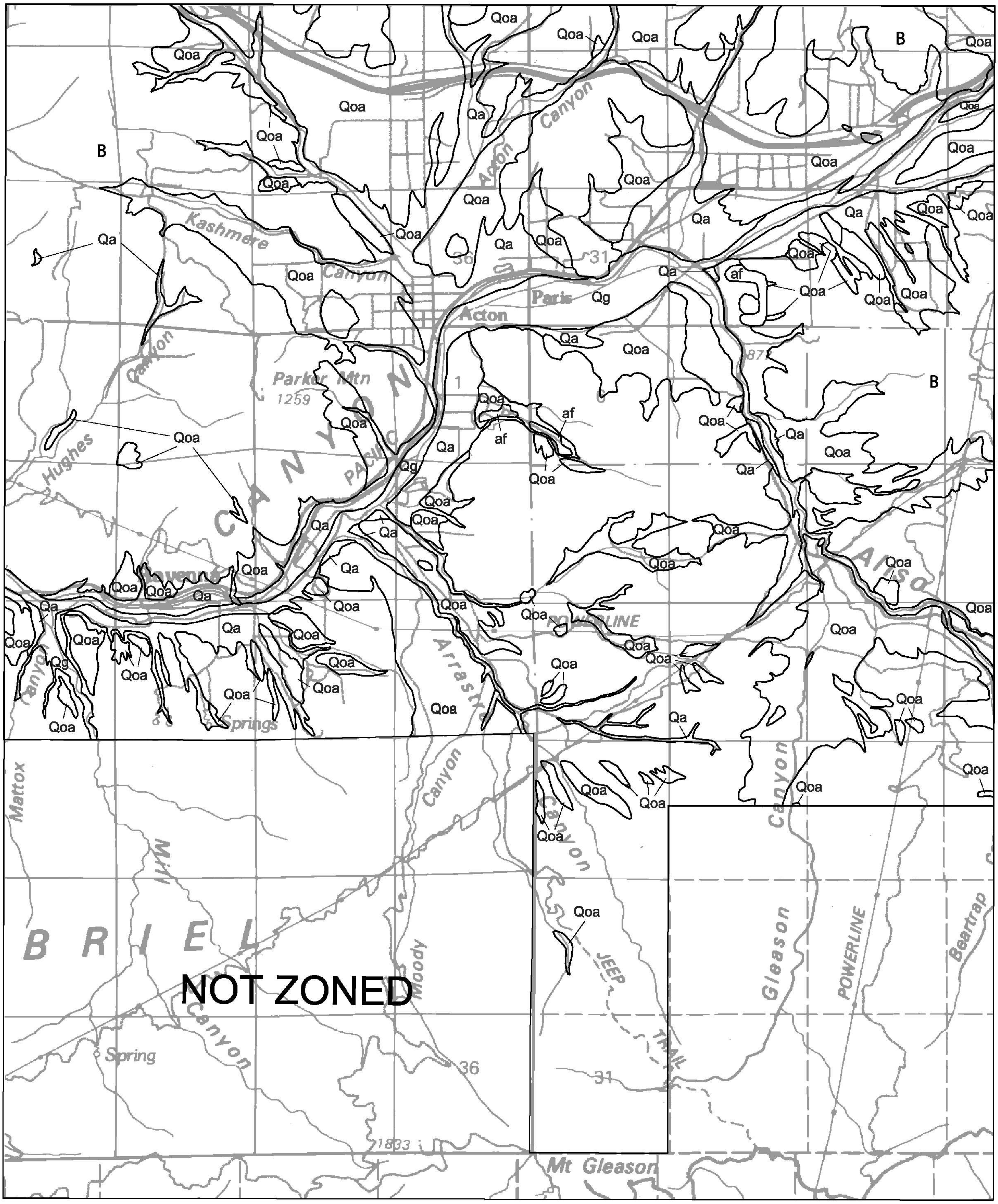
118°15'

34°30'



34°22'30"

Base map enlarged from U.S.G.S. 30 x 60-minute series

118°07'30"

ACTON QUADRANGLE

SCALE

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

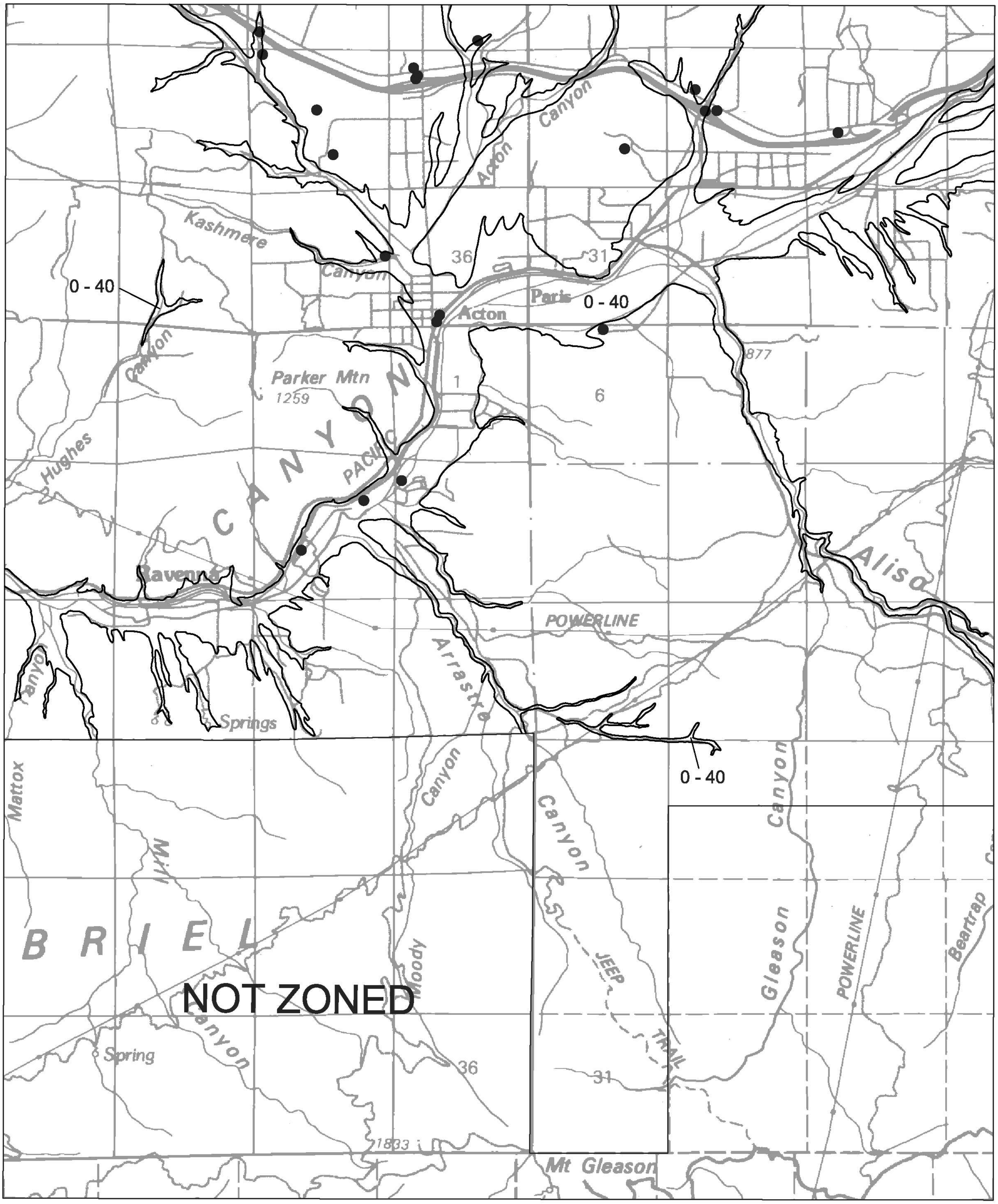
N

B = Pre-Quaternary bedrock.

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

Plate 1.1 Quaternary Geologic Map of portions of the Acton 7.5-Minute Quadrangle, California. Modified from Dibblee (1996).

118°15'
34°30'



34°22'30"
118°07'30"

Base map enlarged from U.S.G.S. 30 x 60-minute series

ACTON QUADRANGLE

SCALE

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

N

0 - 40 Depth to ground water, in feet

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

Geotechnical borings and trenches used in liquefaction evaluation

Plate 1.2 Depth to historically high ground water, and locations of boreholes and trenches used in this study, Acton 7.5-Minute Quadrangle, California.

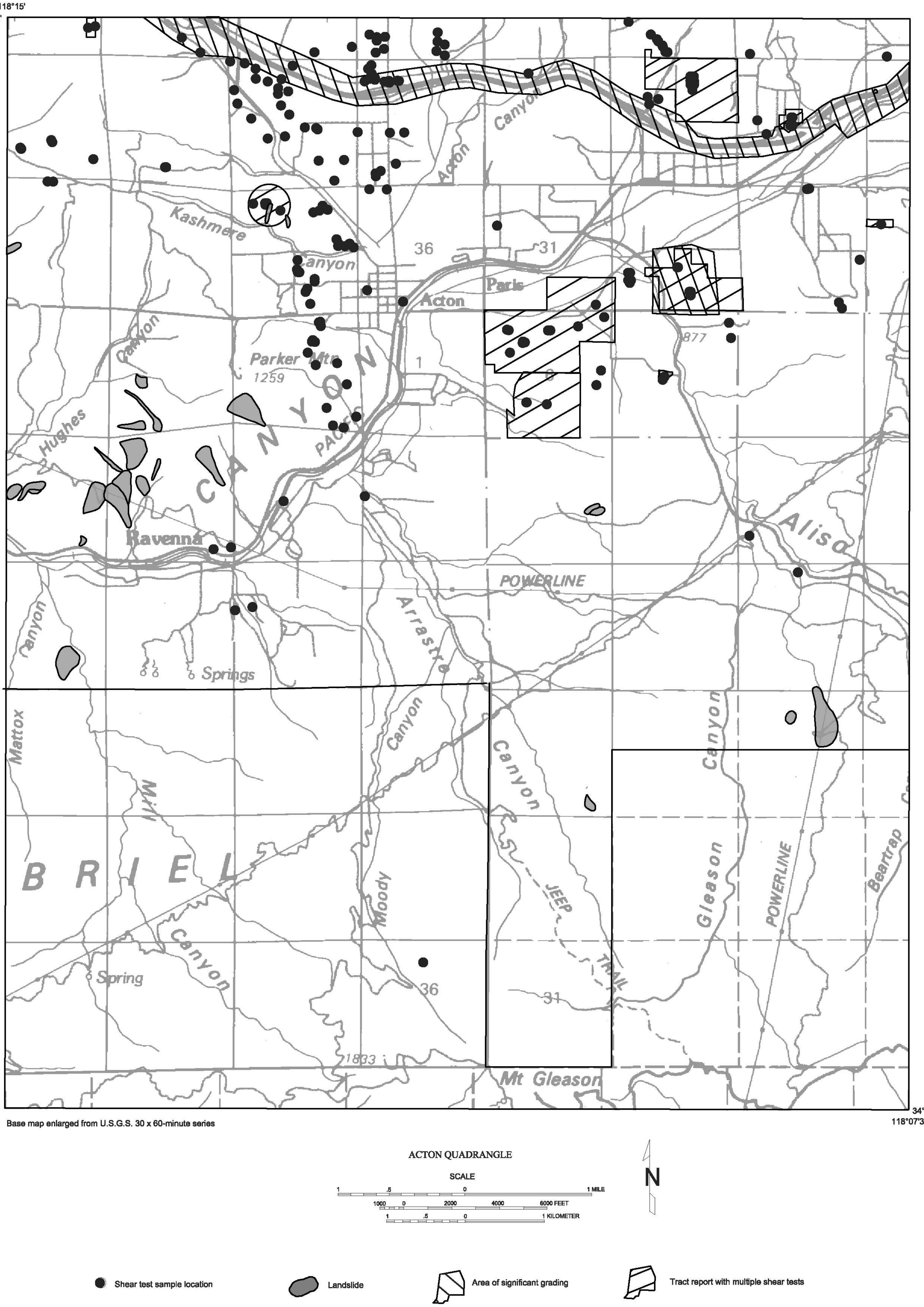


Plate 2.1 Landslide inventory, shear test sample locations, and areas of significant grading, Acton 7.5-Minute Quadrangle, California.